W91321-04-C-0023

LOGANEnergy Corp.

Mid-term Project Report

Proton Exchange Membrane (PEM) Fuel Cell Demonstration
Of Domestically Produced PEM Fuel Cells in Military Facilities

US Army Corps of Engineer
Engineer Research and Development Center
Construction Engineering Research Laboratory
Broad Agency Announcement CERL-BAA-FY03

Camp Mabry ANGB, Austin, TX

July 17, 2006

Executive Summary

Under terms of its FY'03 DOD Proton Exchange Membrane (PEM) Demonstration Contract with ERDC/CERL, LOGANEnergy in cooperation with Austin Energy has installed and currently operates one Plug Power GenSys 5kWe Combined Heat and Power fuel cell power plant (see Appendix section 2 for detailed specifications) at Camp Mabry Army National Guard Base, Austin, TX. The site on the base selected for the one-year demonstration project is the Texas National Guard Museum. The unit is electrically configured to provide grid parallel service to the site. In addition it is thermally integrated with a small HVAC desiccant air unit to provide seasonally warm or cool dry air to benefit moisture sensitive displays in the museum. The project has been operational since October 20, 2005. It is anticipated that the project will add $1,040.87 annual energy costs to Camp Mabry during the period of performance. At the time of this report, July 14, 2006, the additional energy cost has been $715.97. The Camp Mabry ANGB POC for this project is Michael Wolf who can be reached at the following address and phone number:
mwolf@pollution.org
512.782.5001

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Proposal – Proton Exchange Membrane (PEM) Fuel Cell Demonstration of Domestically Produced Residential PEM Fuel Cells in Military Facilities

1.0 Descriptive Title

LOGANEnergy Corp. Small Scale PEM 2004 Demonstration Project at Camp Mabry ANGB, Austin, TX

2.0 Name, Address and Related Company Information

LOGANEnergy Corporation

1080 Holcomb Bridge Road
BLDG 100- 175
Roswell, GA 30076
(770) 650- 6388

DUNS 01-562-6211
CAGE Code 09QC3
TIN 58-2292769

LOGANEnergy Corporation is a private Fuel Cell Energy Services company founded in 1994. LOGAN specializes in planning, developing, and maintaining fuel cell projects. In addition, the company works closely with manufacturers to implement their product commercialization strategies. Over the past decade, LOGAN has analyzed hundreds of fuel cell applications. The company has acquired technical skills and expertise by designing, installing and operating over 30 commercial and small-scale fuel cell projects totaling over 7 megawatts of power. These services have been provided to the Department of Defense, fuel cell manufacturers, utilities, and other commercial customers. Presently, LOGAN supports 30 Phosphoric Acid Fuel Cells (PAFC) and PEM fuel cell projects at 21 locations in 12 states, and has agreements to install 22 new projects in the US and the UK over the next 18 months.

3.0 Production Capability of the Manufacturer

Plug Power manufactures a line of PEM fuel cell products at its production facility in Latham, NY. The facility produces three lines of PEM products including the 5kW GenSys5C natural gas unit, the GenSys5P Liquid Propane Gas (LPG) unit, and the GenCor 5kW standby power system. The current facility has the capability of manufacturing 10,000 units annually. Plug Power will support this project by providing remote monitoring, telephonic field support, overnight parts supply, and customer support. These services are intended to enhance the reliability and performance of the unit and achieve the highest possible customer satisfaction. Vinny Cassala is the Plug Power point of contact for this project. His phone number is 518.782.7700 ex1228, and his email address is vincent_cassala@plugpower.com.

4.0 Principal Investigator(s)

Name	Chris Davis	Keith Spitznagel
Title	Chief Operating Office	Vice President Market Engagement
Company	LoganEnergy Corp.	LoganEnergy Corp.
Phone	770.650.6388 x 101	860.210.8050
Fax	770.650.7317	770.650.7317
Email	cdavis@loganenergy.com	kspitznagel@loganenergy.com

5.0 Authorized Negotiator(s)

Name	Chris Davis	Keith Spitznagel
Title	Chief Operating Office	Vice President Market Engagement
Company	LoganEnergy Corp.	LoganEnergy Corp.
Phone	770.650.6388 x 101	860.210.8050
Fax	770.650.7317	770.650.7317
Email	cdavis@loganenergy.com	kspitznagel@loganenergy.com

6.0 Past Relevant Performance Information

a) Contract: PC25 Fuel Cell Service and Maintenance Contract #X1237022
Contract Value - $120,000

Merck & Company
Ms. Stephanie Chapman
Merck & Company
Bldg 53 Northside
Linden Ave. Gate
Linden, NJ 07036
(732) 594-1686

Four-year PC25 PM Services Maintenance Agreement.
In November 2002 Merck & Company issued a four-year contract to LOGAN to provide fuel cell service, maintenance and operational support for one PC25C fuel cell installed at their Rahway, NJ plant. During the contract period the power plant has operated at 94% availability.

b) Contract: Plug Power Service and Maintenance Agreement to support one 5kWe GenSys 5C and one 5kWe GenSys 5P PEM power plant at NAS Patuxant River, MD.
Contract Value - $52,000

Plug Power
Vinny Cassala
968 Albany Shaker Rd.
Latham, NY 12110
(518) 782-7700 ex 1228

c) Contract: A Partners LLC Commercial Fuel Cell Project Design, Installation and 5-year service and maintenance agreement on 600kW UTC PC25 power block.
Contract # A Partners LLC, 12/31/01
Contract Value - $5,700,000

Mr. Ron Allison
A Partner LLC
1171 Fulton Mall
Fresno, CA 93721
(559) 233-3262

7.0 Host Facility Information

Camp Mabry, named after Brigadier General Woodford H. Mabry, the Adjutant General of Texas from January 23, 1891 to May 4, 1898, is the headquarters of the State Military Forces. The original 90 acres, located on an elevated plain, overlooking the Colorado River about three miles northwest of the Capitol Building in Austin, was selected by a group of prominent citizens, businessmen, and Guardsmen. Governor J.S. Hogg accepted it on behalf of the state in 1892.
Currently, the post houses the Texas Military Forces Academy, which is the second state building constructed, opening on June 15, 1884. The educational facility conducts the Officer Candidate School, the (NCO) Noncommissioned Officer Academy, Medical Specialist Course and numerous other specialized schools. Also located on the post is the Texas National Guard Museum (site of the demonstration project), the United States Property and Fiscal Office, one of two state Combined Support Maintenance Shops, the Texas National Guard Armory Board, the armory of the Headquarters of the 49th Armored Division, a troop medical clinic, a parachute packing and storehouse facility, plus numerous supply and warehouse facilities.
The electrical provider to Camp Mabry is Austin Energy and the natural gas provider is Santana Natural Gas

8.0 Fuel Cell Site Information

The fuel cell was installed on a pad at the rear of the Museum building, pictured at right, in a grid parallel configuration. The building's electrical service and natural gas service were conveniently located a short distance from the pad site. Due to the air dehumidification requirements of the facility (to help preserve the artifacts on display), LOGAN installed a Munters desiccant unit to help lower the humidity of the interior spaces. This provided the opportunity to test a commercial desiccant system using waste heat from a fuel cell. It is hoped this

Figure 1– View of the GenSys5C on its pad at the rear of the Museum building.

approach will provide much higher thermal utilization in contrast to other projects where the heat transfer has typically occurred with a hot water tank.

The fuel cell system installation required 102 man-hours over a 3 week period to complete. The fuel cell system was officially commissioned on October 25, 2005. The fuel cell will typically operate at 2.5kW in a grid parallel configuration with a typical natural gas consumption of 0.33 standard cubic feet per hour (scfh) for the duration of the demonstration.

The photos below show different views of the project during installation.

Figure 2 – Installation trenching for fuel, power and thermal recovery piping. Watt meter and service disconnect are bracketed to the front of the unit.

Figure 3 – Installation of a natural gas regulator and flow meter completes the fuel supply system.

Figure 4 – Photo of building penetrations to provide electrical and thermal energy to the interior service interfaces.

Please see Appendix section 4 for detailed performance charts that describe fuel cell system operations and performance details.

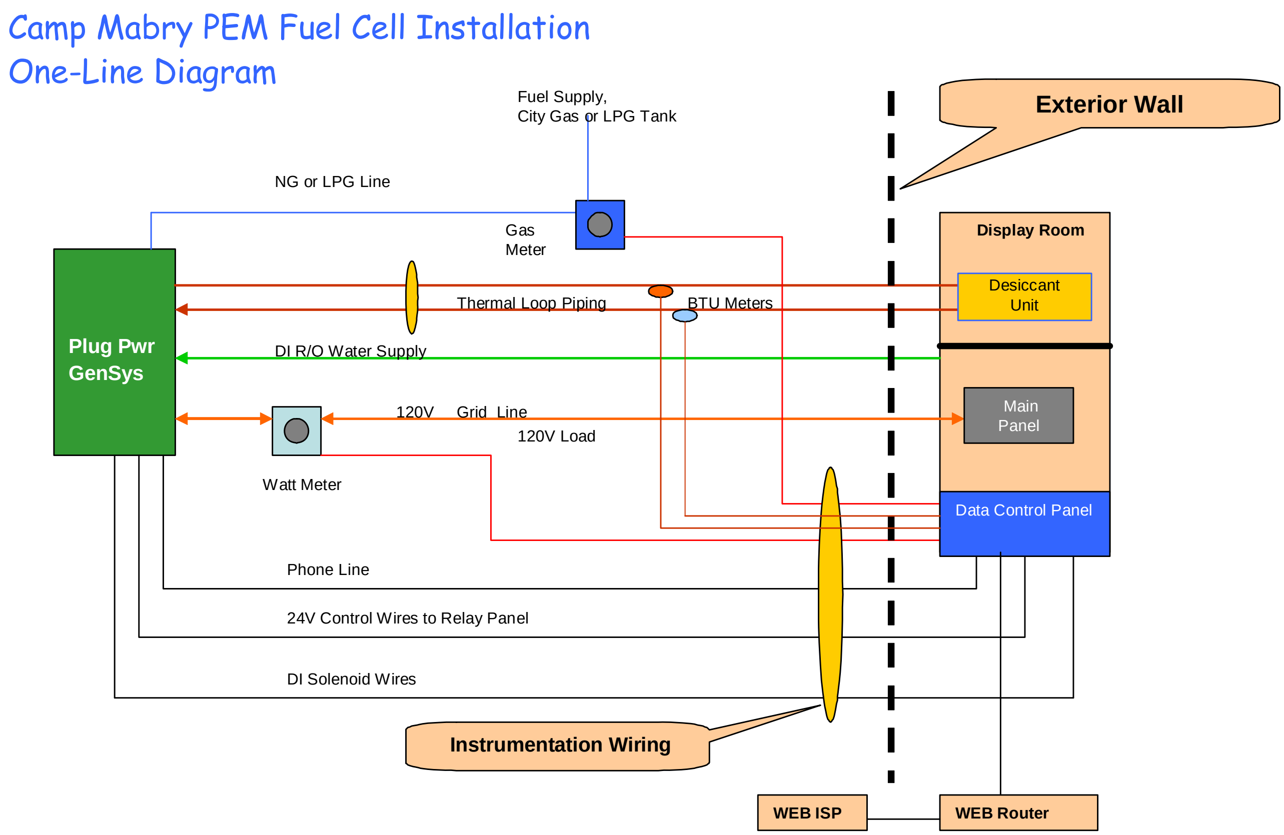


Figure 5 – Diagram of electrical, mechanical, thermal, and communications interfaces between the fuel cell and the host facility.

9.0 Electrical System

The Plug Power GenSys 5C PEM fuel cell power plant provides both gird parallel and grid independent operating configurations for site power management. This capability is an important milestone in the development of the GenSys5 as it approaches product commercialization. The unit has a power output of 110/120 VAC at 60 Hz, and when necessary the voltage can be adjusted to 208vac or 220vac depending upon actual site conditions. At this site the unit will be connected to the facility in a grid parallel configuration dispatching power at 2.5 kW for most of the period of performance. However, subject to the availability of additional funding the unit may operate at 5kW for three months to evaluate the thermal efficiency and output of the DryKor desiccant unit by providing more Btus from the fuel cell to the desiccant unit that would be available at the higher power setting.
The photo at left shows the electrical service panel where the fuel cell will be electrically coupled to the base utility grid at a 50 amp circuit breaker. The electrical closet is conveniently located behind the exterior wall adjacent to the fuel cell pad site.

Figure 6 – Photo of the electrical service closet showing open panel on the right where the fuel cell 110 volt conductor terminates at a 50 amp circuit breaker.

10.0 Thermal Recovery System

While operating at a set point of 2.5 kW, the GenSys5C has a heat rate 35,200Btu/H and offloads approximately 7,800Btu/H to the internally mounted customer heat exchanger. In an ongoing attempt to develop a total fuel cell energy solution that optimizes this waste heat opportunity, LOGAN installed a Munters Corp. H300 Cargocaire desiccant dehumidifier at this site. As Camp Mabry is located in the southern US where high humidity increases air-conditioning loads adds to utility costs, and raises other indoor environmental concerns, LOGAN believes desiccant air-conditioning may be the best use of low quality waste heat from the fuel cell to combat these issues. The Museum has one small desiccant unit currently in service that provides dry indoor air to help preserve the shelf life of numerous items on display, so the idea of installing a second larger desiccant system to improve the indoor air quality in a second display room had great appeal. After reviewing the products offered by several manufacturers, LOGAN selected the Munters H300, which has a long operating life for humidity control at virtually any temperature with the following additional advantages:

- Efficient humidity control for applications including product drying, mold and mildew control, corrosion protection, storage and condensation control.
- Durable unitized body with welded aluminum construction.
- Easy access panel for inspection and maintenance. Simple ductwork connections.
- Compact, low profile design.
- Flow rates of 150-300 scfm.
- Nominal moisture removal; 9.1 lbs/hr at 75F, 50% RH at 300 scfm. Capable of processing saturated, conditioned or outside air.

Figure 7 below is a close up of the Munters H300 unit recently installed at the Camp Mabry PEM demonstration site in Austin, TX. Figure 8 is a photo of the H300 providing dry air to the Vintage Apparel display in the Museum.

Figure 7 – Photo of the Munters H300 Desiccant unit installed at the Texas National Guard Museum, Camp Mabry, TX.

Figure 8 – Photo of the Munters H300 providing desiccated airflow to the Vintage Apparel display at the Museum.

11.0 Data Acquisition System

LOGAN Energy installed a Connected Energy Corporation (CEC) web based Supervisory Control And Data Acquisition (SCADA) system that provides high-speed access to real time monitoring of the power plant. The schematic drawing seen below describes the architecture of the CEC hardware that will support the project. The system provides a comprehensive data acquisition solution and also incorporates remote control, alarming, notification, and reporting functions. The system will pick up and display a number of fuel cell operating parameters on functional display screens including kWH, cell stack voltage, and water management, as well as external instrumentation inputs including Btus, fuel flow, and thermal loop temperatures. CEC's Operations Control Center in Rochester, New York maintains connectivity by means of a Virtual Private Network (VPN) that will link the fuel cell to the center. For access to the demonstration data use the following link and select Camp Mabry once at the Connected Energy site.

www.enerview.com

User: Logan.user
Password: guest

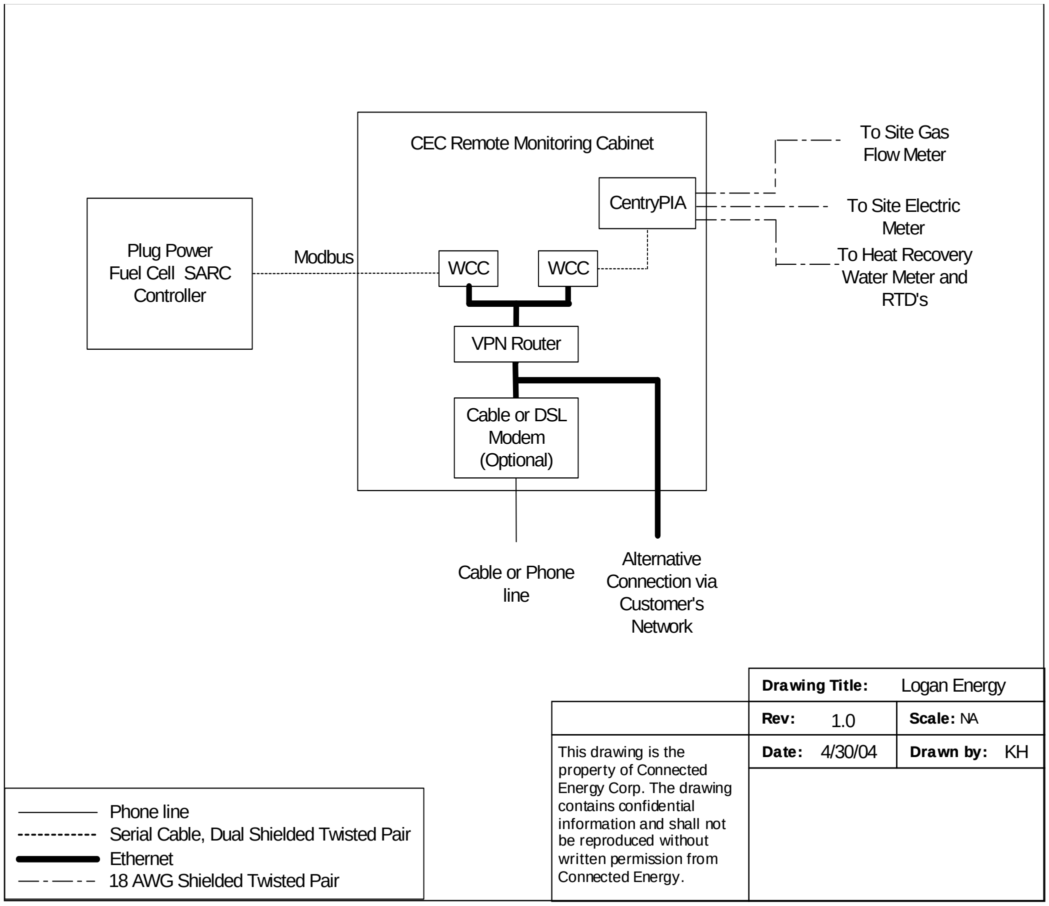


Figure 9 – CEC WEB enabled SCADA terminal hardware and architecture detail.

LOGAN has procured high-speed access to the fuel cell router from a local Internet Service Provider (ISP) company. The base provides local dial tone to a phone jack in the Museum's electrical closet to provide communications with the fuel cell data modem.

12.0 Fuel Supply System

LOGAN connected the fuel cell gas piping into the existing natural gas service line pictured in Figure 3, and installed a flow meter to calculate fuel cell usage as detailed in Paragraph 8.0. A regulator at the fuel cell gas inlet maintains the correct fuel cell operating pressure at 14 inches water column. While operating at a set point of 2.5kWh the Gensys5C consumes 0.33 scfh of fuel.

13.0 Installation Costs

Camp Mabry ANGB

Project Utility Rates				
1) Water (per 1,000 gallons)	$ 1.25			
2) Utility (per KWH)	$ 0.0625			
3) Natural Gas (per MCF)	$ 9.75			
First Cost		**Budgeted**	**Actual**	**Variance**
Plug Power 5 kW SU-1 & Munters Desiccant Dehumidifier		$ 71,934.00	$ 71,934.00	$ -
Shipping		$ 2,400.00	$ 2,078.00	$ 322.00
Installation electrical		$ 5,375.00	$ 5,450.00	$ (75.00)
Installation mechanical & thermal		$ 7,000.00	$ 8,325.00	$ (1,325.00)
Watt Meter, Instrumentation, Web Package		$ 11,090.00	$ 11,270.00	$ (180.00)
Site Prep, labor materials		$ 825.00	$ 1,075.00	$ (250.00)
Technical Supervision/Start-up		$ 2,500.00	$ 2,500.00	$ -
Total		**$ 101,124.00**	**$ 102,632.00**	**$ (1,508.00)**
Assume Five Year Simple Payback		$ 20,224.80	$ 20,526.40	

Forcast Operating Expenses	Volume	$/Hr	$/ Yr	
Natural Gas Mcf/ hr @ 2.5kW	0.0330	$ 0.32	$ 2,536.68	
Water Gallons per Year	14,016		$ 17.52	
Total Annual Operating Cost				$ 2,554.20

Economic Summary		
Forcast Annual kWH	19710	
Annual Cost of Operating Power Plant	$ 0.130	kWH
Credit Annual Thermal Recovery Rate	$ (0.014)	kWH
Project Net Operating Cost	$ 0.1153	kWH
Displaced Utility cost	$ 0.0625	kWH
Energy Savings (Cost)	($0.053)	kWH
Annual Energy Savings (Cost)	($1,040.87)	

14.0 Acceptance Test

An 8-hour acceptance test concluded on October 20, 2005 following the completion of all the commissioning and acceptance tasks listed in the Checklist attached below. It was the first successful start-up of the system. Please see Appendix Section 1 for documentation of the test done by the technician.

15.0 Other Pertinent Information

Appendix Section 3, below, contains a copy of the Austin Energy Interconnection Guide that publicizes regulations required by the utility, which compliance is mandatory in order to operate a gird parallel generator on their system. This was the first such instance in 4 years covering over 50 separate installations in the PEM program in which LOGAN required to certify the installation to a utility standard. Fortunately the GenSys5C is compliant with the requirements and the installation, itself, followed the customary and design and construction practices required by the document. LOGAN believes two important points follow from this experience:

a. Austin Energy is aware of changes that are reshaping the power service industry and the utility is taking proactive measures that will enable an orderly expansion of DG products into the marketplace, and
b. The Interconnection Guide is very clear and concise document that puts a reasonable burden on the Distributed Generation customer to meet minimal product safety requirements and approved interconnection standards.

Appendix

Section 1

Installation and Site Commissioning Reports

Installation Acceptance Test Report

Camp Mabry, Texas SU1-322

Installation Check List

TASK	Initials	DATE	TIME (hrs)
Batteries Installed	WH		2
Stack Installed	WH		4
Stack Coolant Installed	WH		4
Air Purged from Stack Coolant	WH		1
Radiator Coolant Installed	WH		3
Air Purged from Radiator Coolant	WH		1
J3 Cable Installed	WH		4
J3 Cable Wiring Tested	WH		2
Inverter Power Cable Installed	WH		16
Inverter Power Polarity Correct	WH		2
RS 232 /Modem Cable Installed	WH		12
Natural Gas Pipe Installed	WH		16
DI Water / Heat Trace Installed	WH		16
Drain Tubing Installed	WH		1

Commissioning Check List and Acceptance Test

TASK	Initials	DATE	TIME (hrs)
Controls Powered Up and Communication OK	WH		4
SARC Name Correct	WH		1
Start-Up Initiated	WH		1
Coolant Leak Checked	WH		1
Flammable Gas Leak Checked	WH		1
Data Logging to Central Computer	WH		2
System Run for 8 Hours with No Failures	WH		8

Section 2

Plug Power GenSys5C Specifications

Plug Power GenSys 5C

• Dimensions 84 1/2" x 32" x 68 1/4"

• Performance Continuous Power Rating 5kWe (9kWth)
  Power Output 2.5-5kWe (3-9kWth)
  Voltage 120/240 VAC @ 60Hz
  Power Quality IEEE 519, Grid Interconnect IEEE P1547
  Emissions NOX <1ppm...SOX <1ppm
• Noise <60 dBa @ 1 meter
• Operating Conditions Temperature 0°F to 104°F
• Elevation 0 to 6000 feet
• Installation Outdoor
• Electrical Connection, Grid Parallel/Grid Independent
• Fuel, Natural Gas
• Certifications Power Generation, CSA International
• Power Conditioning UL 1741— Electromagnetic Compliance FCC Class B —

Section 3

AUSTIN ENERGY'S TECHNICAL REQUIREMENTS FOR DISTRIBUTED GENERATION INTERCONNECTION (for facilities under 20 kW)

1. **Manual Disconnect**
   A manual load break disconnect switch that provides clear indication of the switch position shall be available at the customer's main service point to provide a separation point between the customer's electrical generation system and Austin Energy's (AE) electrical system. AE will coordinate and approve the location of the disconnect switch. The disconnect switch shall be easily visible, mounted separately from the metering equipment, readily accessible to AE personnel at all times, and capable of being locked in the open position with an AE padlock. Austin Energy reserves the right to open the disconnect switch isolating the customer's electrical generating system (which may or may not include the customer's load) from AE's electrical system for the following reasons:

   a. To facilitate maintenance or repair of AE's electrical system;
   b. When emergency conditions exist on AE's electrical system;
   c. When the customer's electrical generating system is determined to be operating in a hazardous or unsafe manner or unduly affecting AE's voltage waveform;
   d. When the customer's electrical generating system is determined to be adversely affecting other electric consumers on the AE system;
   e. Failure of the customer to comply with applicable codes, regulations and standards in effect at that time;
   f. Failure to abide by any contractual arrangement or operating agreement with Austin Energy.

2. **Voltage**
   AE shall endeavor to maintain the distribution voltages on the electrical system but shall not be responsible for factors or circumstances beyond its control. The customer shall provide an automatic method of disconnecting generation equipment from AE's electrical system within 10 cycles should a voltage deviation greater than +5% or -10% from normal be sustained for more than 30 seconds (1800 cycles) or a voltage deviation greater than +10% or -30% from normal be sustained for more than 10 cycles. If high or low voltage complaints or flicker complaints result from the operation of the customer's electrical generation, the customer's generating system shall be disconnected until the problem is resolved.

3. **Frequency**
   AE shall endeavor to maintain a 60-hertz nominal frequency on the electrical system. The customer shall provide an automatic method of disconnecting generation equipment from AE's electrical system within 15 cycles should a deviation in frequency of +0.5Hz or -0.7Hz from normal occur.

4. **Harmonics**
   In accordance with IEEE 519, the total harmonic distortion (THD) of voltage shall not exceed 5% of a pure sine wave of 60-hertz frequency or 3% of the 60-hertz frequency for any individual harmonic when measured at the point of interconnection with AE’s electrical system. Also, the total current distortion shall not exceed 5% of the fundamental frequency sine wave. If harmonics beyond the allowable range result from the operation of the customer's electrical generation, the customer's generating system shall be disconnected until the problem is resolved.

5. **Flicker**
   The distributed generation facility shall not cause excessive voltage flicker on AE’s electrical system. This flicker shall not exceed 3% voltage dip, in accordance with IEEE 519 (Section 10.5), as measured at the point of interconnection.

6. **Power Factor**
   The customer's electrical generation system shall be designed, operated and controlled at all times to provide reactive power requirements at the point of interconnection from 0.95 lagging to 0.95 leading power factor. Induction generators shall have static capacitors that provide at least 95% of the magnetizing current requirements of the induction generator field. Austin Energy may, in the interest of safety, authorize the omission of capacitors. However, where capacitors are used for power factor correction, additional protective devices may be required to guard against self-excitation of the customer's generator field.

7. **Loss of Source**
   The customer shall provide approved protective equipment necessary to immediately, completely and automatically disconnect the customer’s electrical generation equipment from AE’s electrical system in the event of a fault on the customer's system, a fault on AE’s system or loss of source on AE’s system. Such protective equipment shall conform to the criteria specified in UL 1741. The customer’s generating system shall automatically disconnect from the grid within 10 cycles if the voltage on one or more phases falls and stays below 70% of nominal voltage for at least 10 cycles. The automatic disconnecting device may be of the manual or automatic reclose type and shall not be capable of reclosing until after the AE’s service voltage and frequency are restored to within the normal operating range and the system is stabilized.

8. **Coordination and synchronization**
   The customer shall be solely responsible for coordination and synchronization of the customer's electrical generating system with all aspects of AE’s electrical system, and the customer assumes all responsibility for damage or loss that may occur from improper coordination and synchronization of its generating system with AE’s electrical system. The customer should be aware that the phase rotation used by Austin Energy is C-B-A.

9. **Metering**

The actual metering equipment required, its voltage rating, number of phases and wires, size, current transformers, number of input and associated memory is dependent upon the type, size and location of the electric service provided. In situations where power may flow both in and out of the customer's electrical system, power flowing into the customer's electrical system will be measured separately from power flowing out of the customer's electrical system. AE will provide, subject to existing rate schedules at the time of application, the metering equipment necessary to measure capacity and energy delivered to and from the customer.

10. **Interconnection Study**

If AE determines that an interconnection study is necessary, AE shall perform the study under reasonable terms and conditions agreed upon by both the customer and Austin Energy and at the customer's sole expense. No interconnection study shall be necessary and no study fee will be charged if the proposed generation site is not on a networked secondary and if all of the following apply:

a. Proposed generation equipment is pre-certified
    i. Generation equipment that are less than 20 kW AC shall be considered pre-certified if a UL 1741 listed inverter is used as well as UL 1703 listed PV modules.
b. Proposed generation system does not expect to export more than 15% of total load on the feeder
c. Proposed generation system does not contribute more than 25% of the maximum possible short circuit current of the feeder

11. **Protection requirements**

The distributed generation facility must have interrupting devices capable of interrupting the maximum available fault current, an interconnection disconnect device, a generator disconnect device, an over-voltage trip, an under-voltage trip, an over/under frequency trip and a manual or automatic synchronizing check (for facilities with stand-alone capability). Facilities rated over 10kW, three phase, must also have reverse power sensing and either a ground over-voltage or a ground over-current trip depending on the grounding system. Grounding shall be done in accordance with UL 1741 and NEC Article 250.

12. **<u>Additional requirements for three-phase generators</u>**

a. Synchronous machines

i. The distributed generation facility's circuit breakers shall be three-phase devices with electronic or electromechanical control.
ii. The Customer is solely responsible for proper synchronization of its generator with the City of Austin's system.
iii. The excitation system response ratio shall not be less than 0.5.
iv. The generator's excitation system shall conform to the field voltage versus time criteria specified in ANSI Standard C50.13-1989.

b. Induction machines

i. The induction machines used for generation may be brought up to synchronous speed if it can be demonstrated that the initial voltage drop at the point of interconnection is within the flicker limits specified in this document.

c. Inverters

i. Line-commutated inverters do not require synchronizing equipment.
ii. Self-commutated inverters require synchronizing equipment.

13. **<u>Conformance to standards</u>**

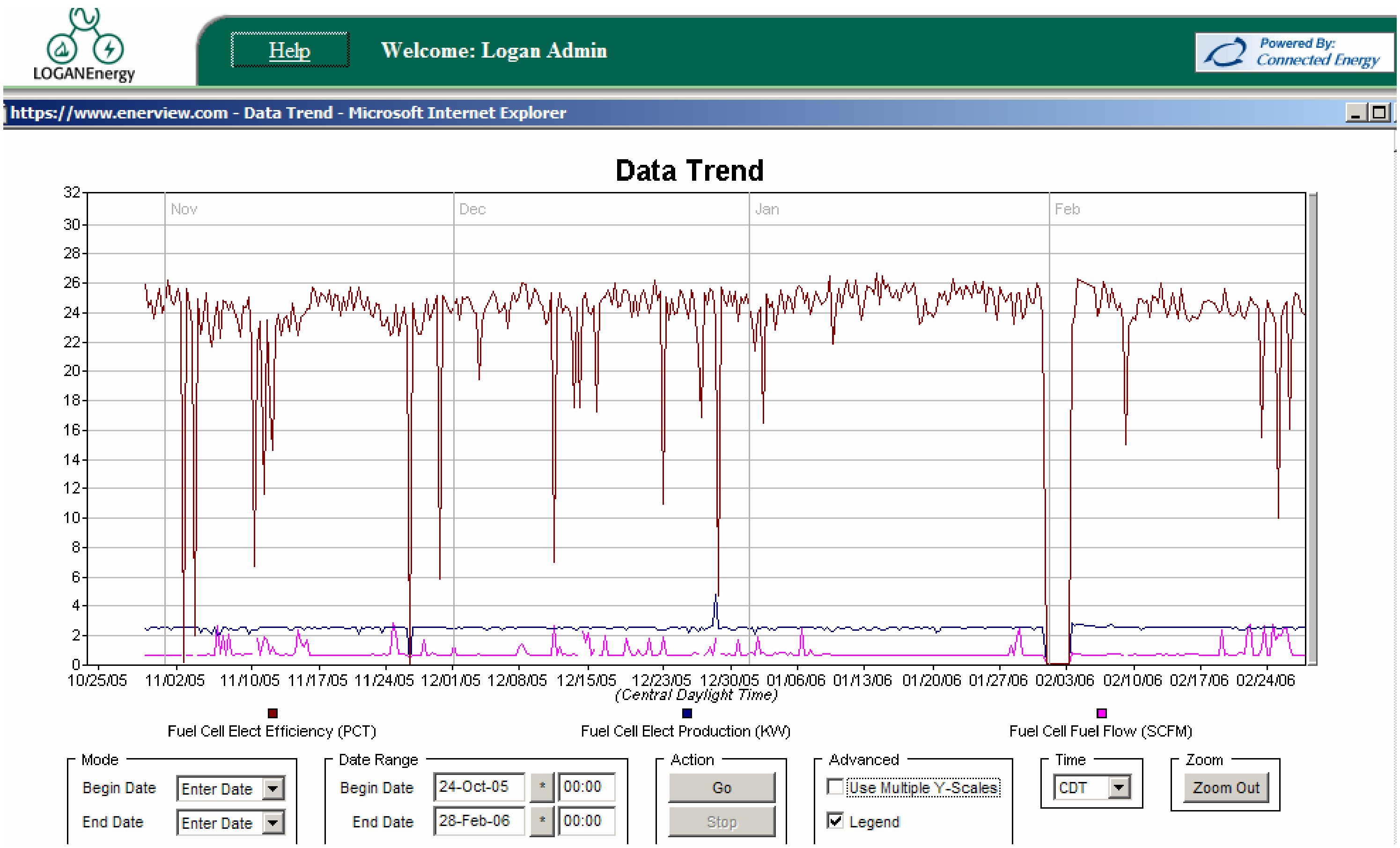
The distributed generation equipment shall be designed, installed, operated and maintained in accordance with, but not limited to, ANSI standards, UL standards, IEEE standards, the National Electrical Code, ERCOT Operating Guides and any other applicable local, state or federal codes and statutes. In the case of a conflict between the requirements in this document and any of those standards or codes, this document shall prevail.

Rev.3 5-18-04
Reliability & Power Quality

Section 4

Performance Charts and Graphs

This chart immediately below plots fuel cell electric efficiency against electric generation and fuel flow.



The chart below plots the Munters desiccant unit's inlet and outlet air humidity against overall thermal efficiency.